

US008362662B2

(12) **United States Patent**
De Filippis

(10) **Patent No.:** **US 8,362,662 B2**
(45) **Date of Patent:** **Jan. 29, 2013**

(54) **ELECTRIC MACHINE HAVING A HEAT DISSIPATING CONSTRUCTION**

(75) Inventor: **Pietro De Filippis**, Varazze (IT)

(73) Assignee: **SPAL AUTOMOTIVE S.r.l.** (IT)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 158 days.

(21) Appl. No.: **12/671,779**

(22) PCT Filed: **Jul. 23, 2008**

(86) PCT No.: **PCT/IB2008/002017**

§ 371 (c)(1),
(2), (4) Date: **Mar. 1, 2010**

(87) PCT Pub. No.: **WO2009/019562**

PCT Pub. Date: **Feb. 12, 2009**

(65) **Prior Publication Data**

US 2010/0171380 A1 Jul. 8, 2010

(30) **Foreign Application Priority Data**

Aug. 7, 2007 (IT) BO2007A0576

(51) **Int. Cl.**
H02K 9/00 (2006.01)
H02K 3/48 (2006.01)
H02K 3/52 (2006.01)

(52) **U.S. Cl.** 310/64; 310/431; 310/214; 310/254.1; 29/596

(58) **Field of Classification Search** 310/64, 310/65, 52, 431, 89, 214, 215, 51, 49.13, 310/254.1, 260, 400-417

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,905,448	A *	9/1975	Kawakami et al.	181/172
5,608,280	A *	3/1997	Tamemoto et al.	310/239
6,201,321	B1	3/2001	Mosciatti	
6,211,587	B1 *	4/2001	Enomoto et al.	310/52
6,809,441	B2 *	10/2004	Randall	310/54
2007/0122293	A1 *	5/2007	Sugiyama et al.	417/354
2009/0058206	A1 *	3/2009	Bremner	310/64

FOREIGN PATENT DOCUMENTS

FR		2828027		1/2003
JP		2003269635	A *	9/2003
SU		1686621		10/1991
WO		03012954		2/2003

OTHER PUBLICATIONS

JPO Machine Translation, JP-08130863, Oct. 24, 2011, http://dosier.ipdl.inpit.go.jp/text_trans.html.*

European Search Report dated May 20, 2009 from counterpart patent application.

* cited by examiner

Primary Examiner — Quyen Leung

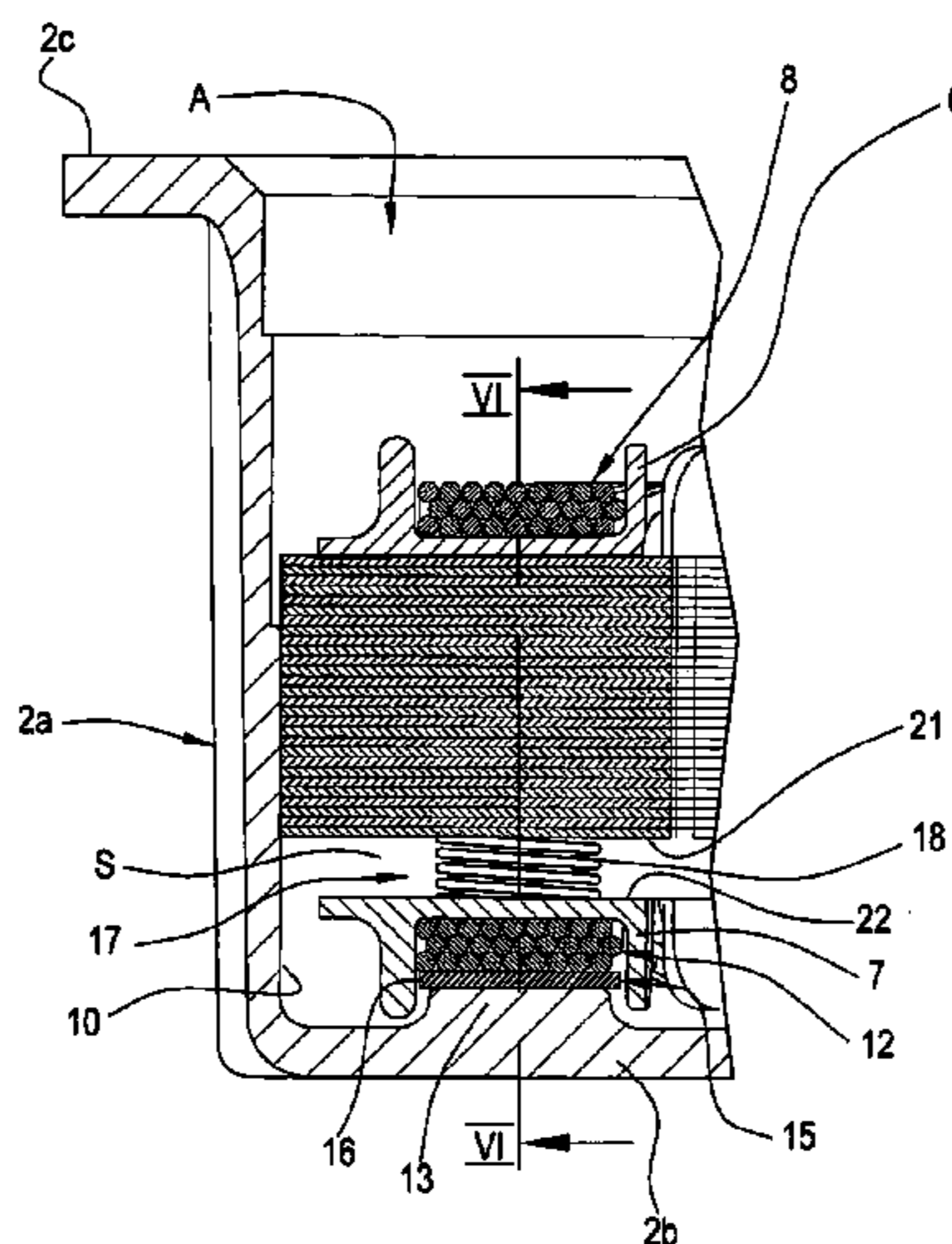
Assistant Examiner — Thomas Truong

(74) *Attorney, Agent, or Firm* — Timothy J. Klima; Shuttleworth & Ingersoll, PLC

(57) **ABSTRACT**

An electric machine comprises an outer casing (2), a rotor and a stator (3) having at least one polar expansion (5) and at least one winding (8) having an annular shape and placed around the polar expansion (5). The casing (2) has a plurality of protrusions (13) each of which holds, by supporting, a corresponding portion (12) of a stator winding (8) to enable heat exchange between the winding (8) and the protrusion (13). Each portion (12) of the winding (8) is electrically insulated from the respective protrusion (13).

10 Claims, 5 Drawing Sheets



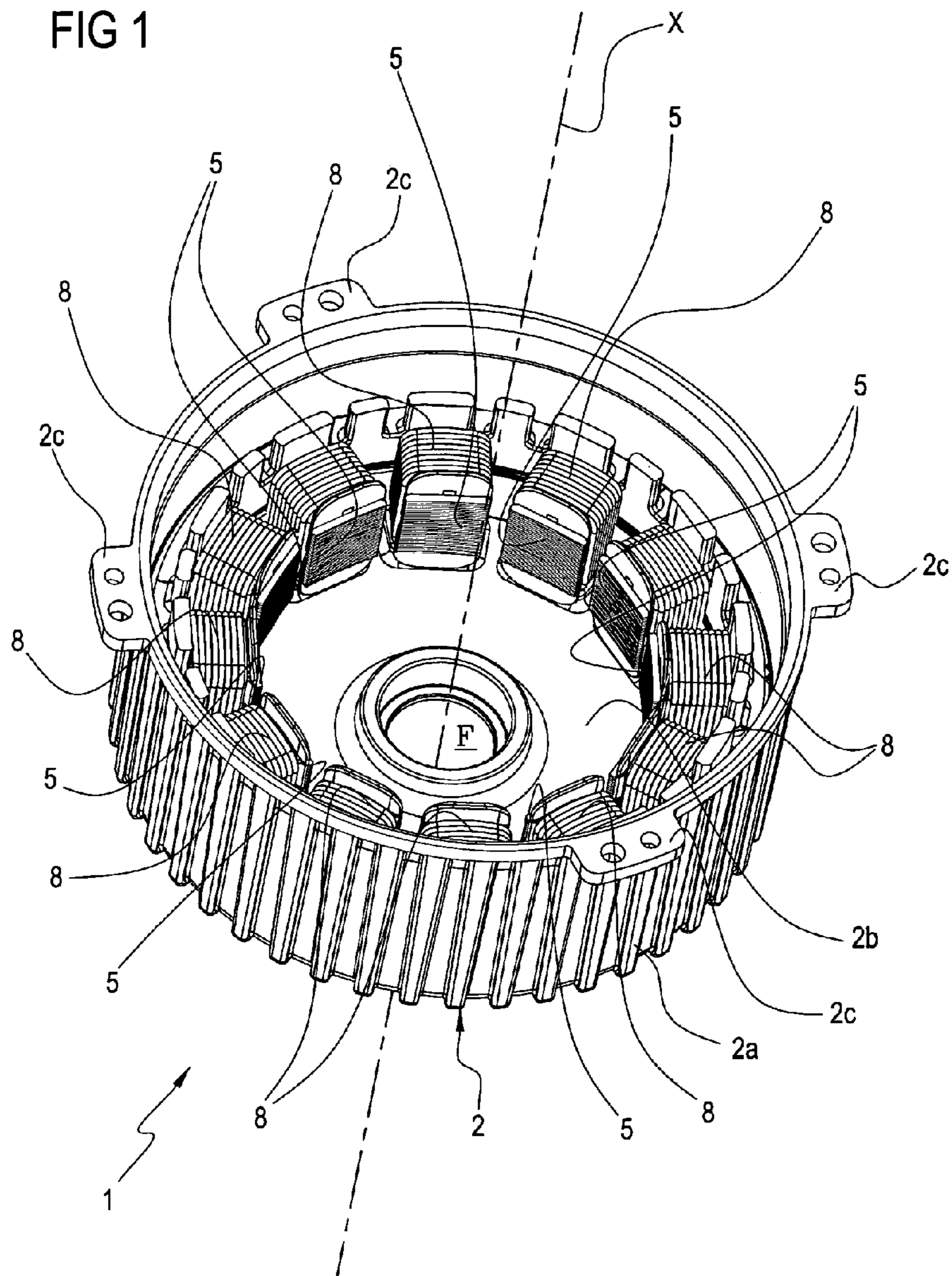


FIG 3a

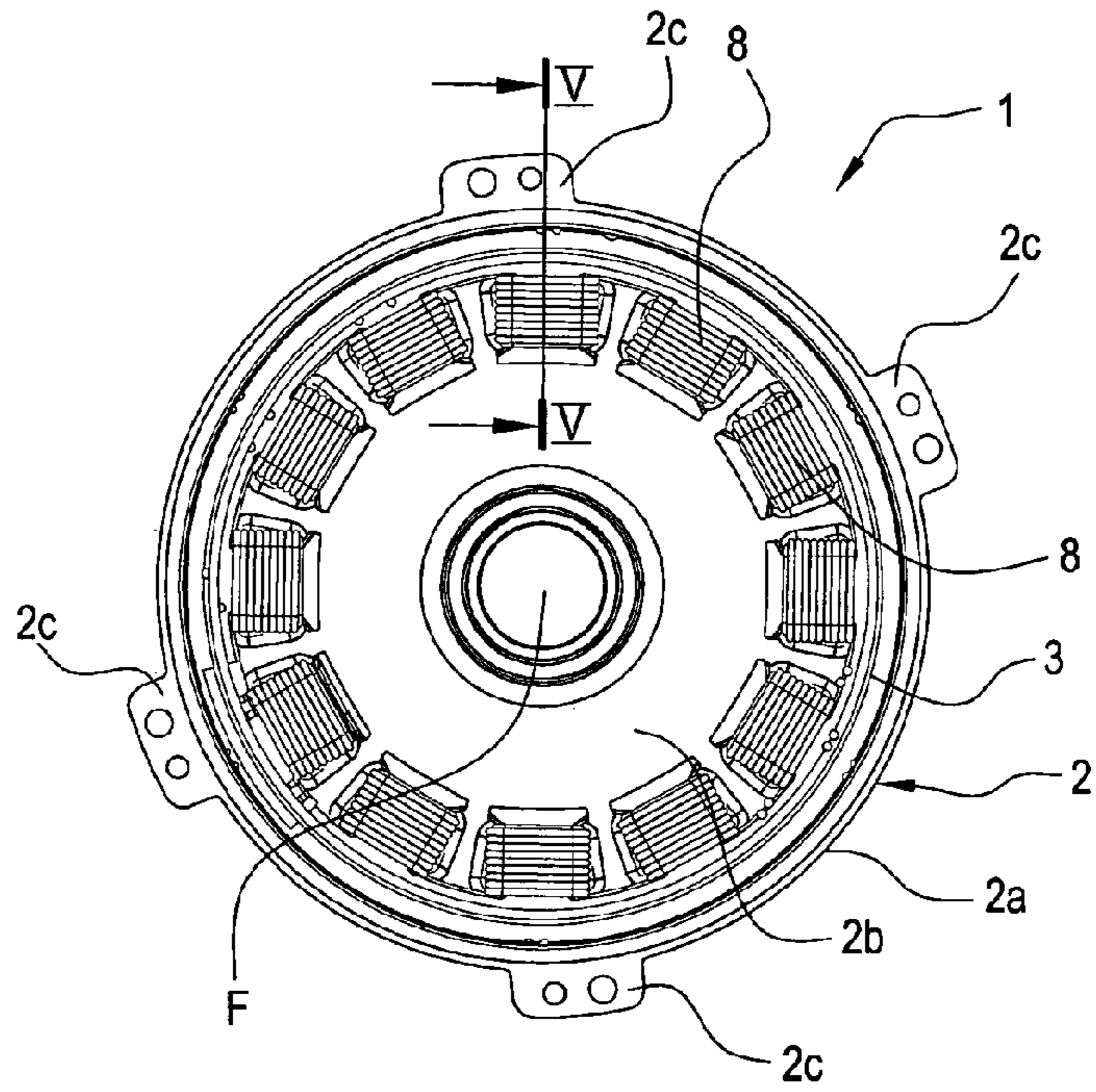


FIG 3b

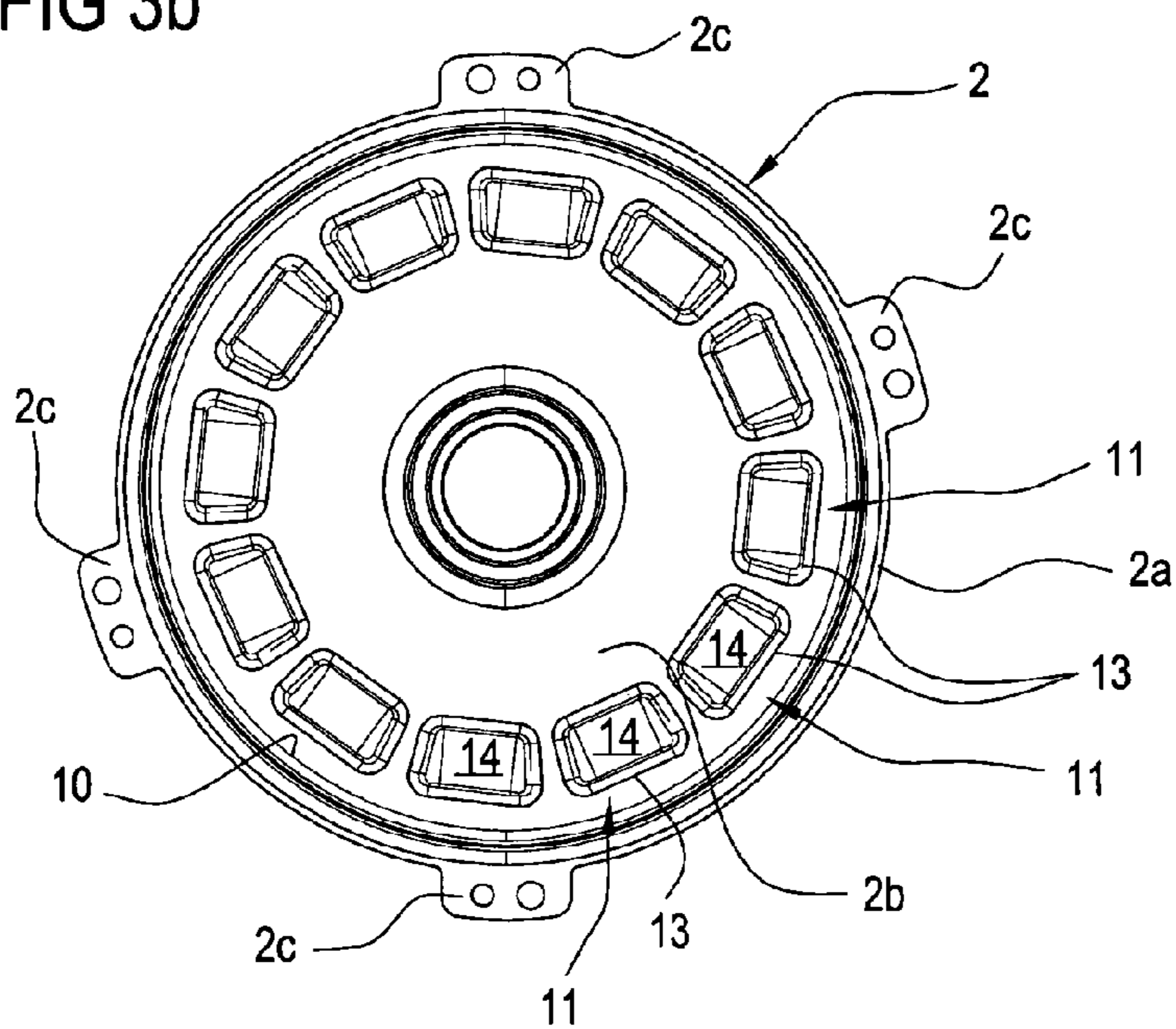
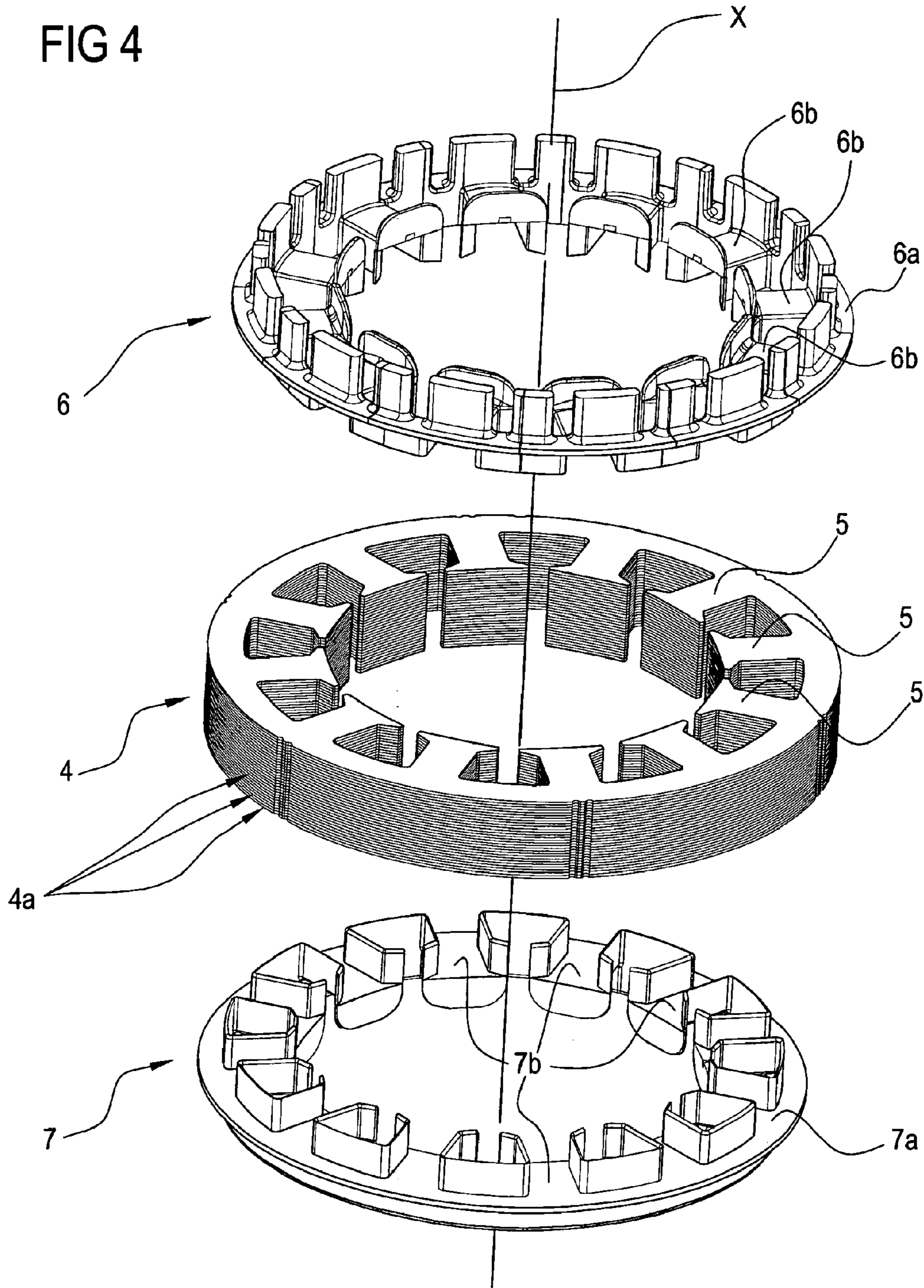
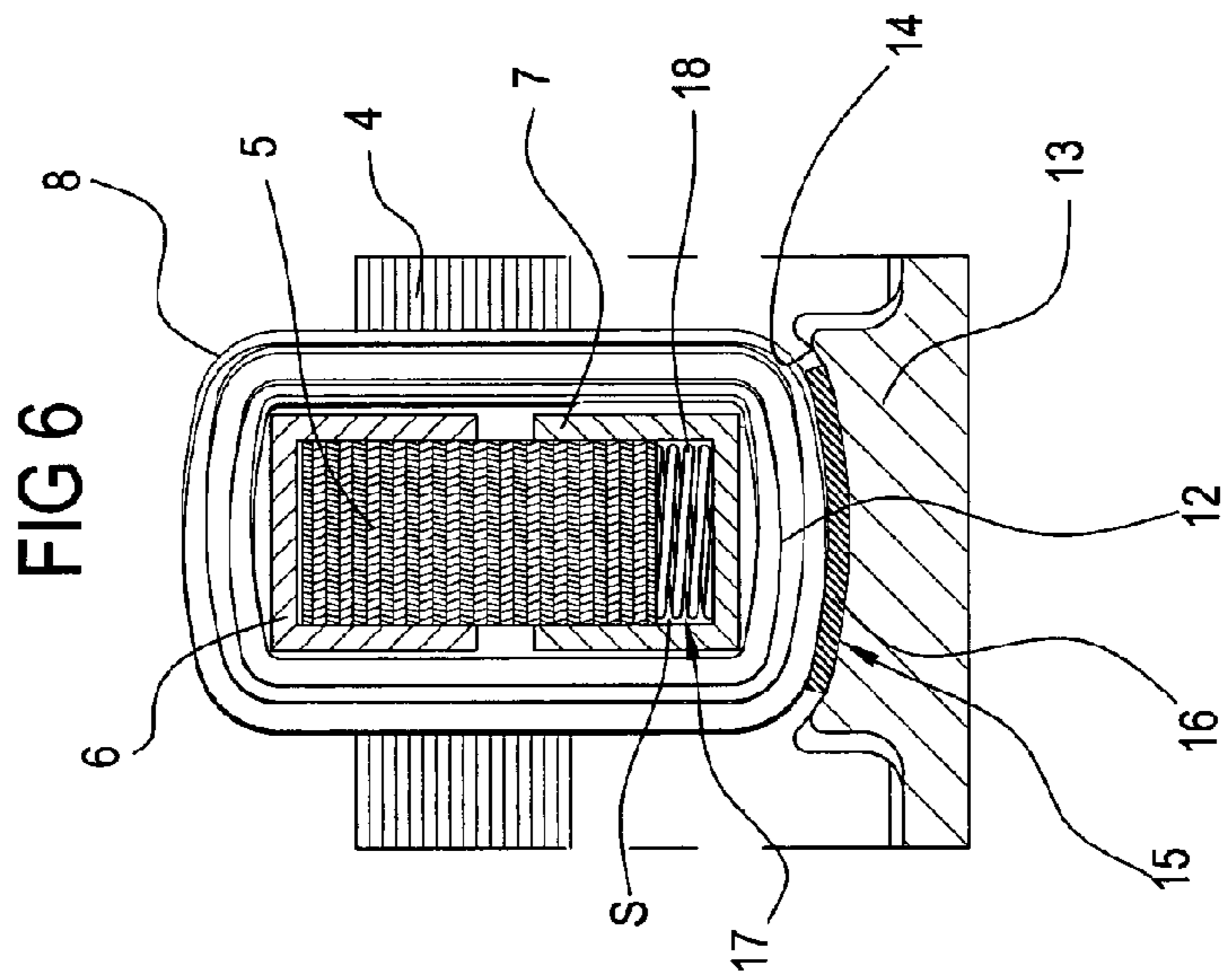
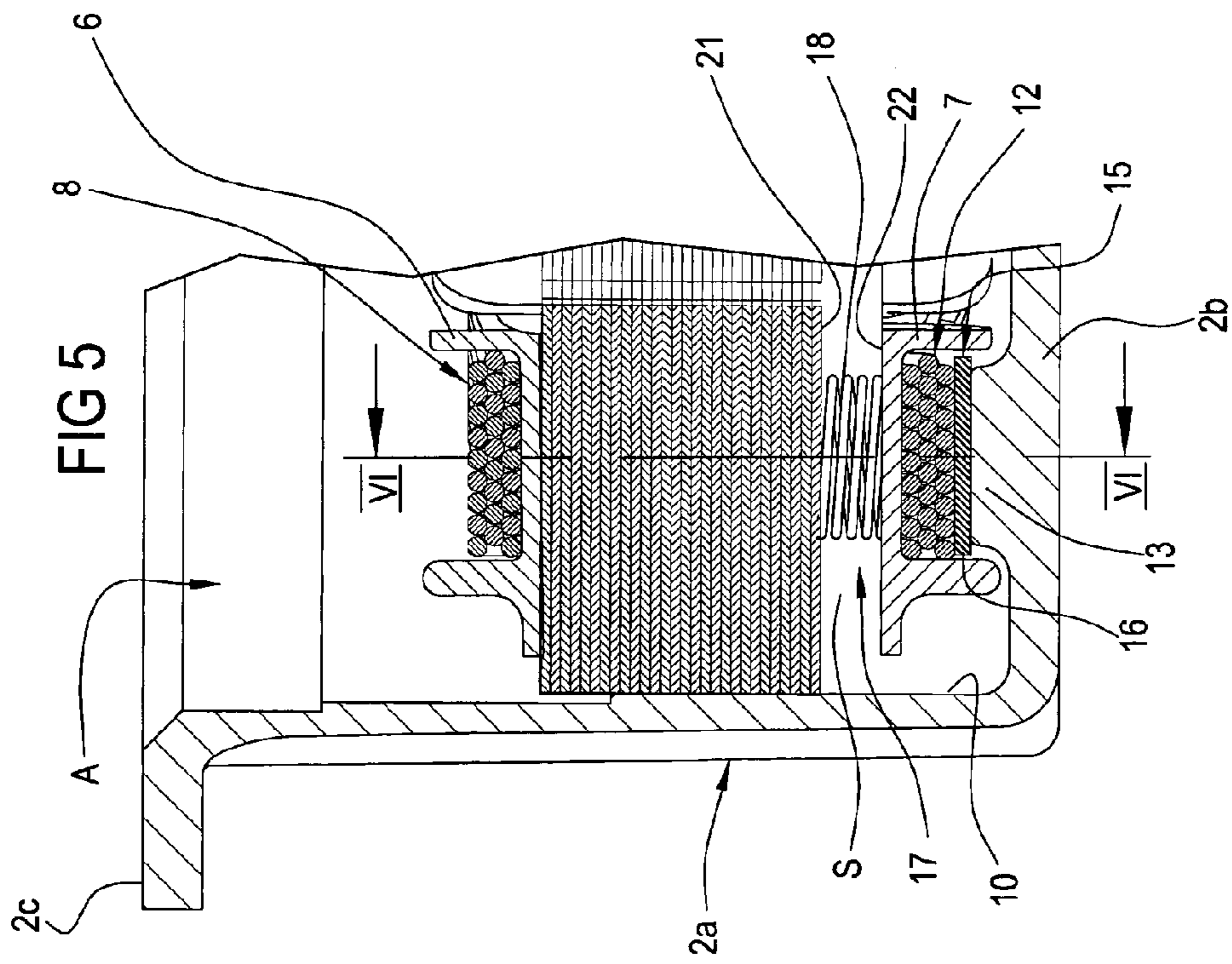


FIG 4





1**ELECTRIC MACHINE HAVING A HEAT
DISSIPATING CONSTRUCTION****CROSS-REFERENCE TO RELATED
APPLICATIONS**

This application is the National Phase of International Application PCT/IB2008/002017 filed Jul. 23, 2008 which designated the U.S. and that International Application was published under PCT Article 21(2) in English.

This application claims priority to Italian Patent Application No. BO2007A000576 filed Aug. 7, 2007, and PCT Application No. PCT/IB2008/002017 filed Jul. 23, 2008, which applications are incorporated by reference herein.

TECHNICAL FIELD

This invention relates to an electric machine.

In particular, the invention relates to a rotary electric machine of the type with stator windings, for example a motor of the type used to drive an electric cooling fan for automotive applications or an electricity generator. Preferably, the electric machine according to this invention is a brushless type electric motor.

The invention also refers to a sealed electric machine, particularly suitable for use in dusty environments or in environments characterized by an atmosphere unsuitable for entering into direct contact with the electromechanical components of the electric machine.

BACKGROUND ART

Prior art windings for an electric machine, whether they are of the stator or rotor type, are made from a plurality of turns of a conductive material, generally copper, formed by winding a lead wire around two or more polar expansions of the stator and/or the rotor of the electric machine. The winding, through which an electric current passes, must be suitably insulated from the polar expansions, which are made from ferromagnetic material. For this purpose, prior art places a layer of electrically insulating material between the winding and the corresponding polar expansion on which it is wound.

Electric currents, including high ones, pass through the winding and cause heating due to the Joule effect which extends through the entire winding and adjacent areas of the electric machine.

In particular, it has been found that the heat produced in this way deteriorates the conductivity properties of the lead wire, which consequently generates a greater resistance to the passage of current causing a high and often unacceptable energy loss.

In addition, the overheating of the winding may result in fast deterioration of the insulation characteristics of the above-mentioned layer of electrically insulating material placed between the winding and the corresponding polar expansion on which it is wound. This results in evident risks of short circuits and permanent damage to the electric machine, which must therefore be replaced or undergo costly maintenance.

This situation is particularly serious in rotary electric machines of the sealed type, in which the windings are immersed in a sealed environment subjected to continuous heating due essentially to the above-mentioned heating caused by the Joule effect. This sealed environment is not subject to an exchange of air, and, under steady-state condi-

2

tions, there may be high temperatures inside this environment which favour overheating of the windings.

DISCLOSURE OF THE INVENTION

The aim of the present invention is therefore to provide an electric machine that is free of the above-mentioned shortcomings.

One aim of the present invention is to provide an electric machine with a high level of reliability.

Another aim of the invention is to provide an electric machine which makes best use of the available power, minimising the energy losses.

The stated technical purposes and aims, and others, are substantially achieved by an electric machine as described in claim **1** and in one or more of the claims dependent thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the present invention are more apparent in the detailed description below, with reference to a preferred, non-limiting, embodiment of an electric machine, as illustrated in the accompanying drawings, in which:

FIG. **1** illustrates a perspective view of a detail of an electric machine according to the present invention, with some parts cut away to better illustrate others;

FIG. **2** illustrates a perspective exploded view of the detail of FIG. **1**;

FIG. **3a** illustrates a plan view of the detail of FIG. **1**;

FIG. **3b** illustrates a plan view of a first portion of the detail of FIG. **1**;

FIG. **4** illustrates a perspective exploded view of a second portion of the detail of FIG. **1**;

FIG. **5** illustrates a section view of the detail of FIG. **1** through the line V-V shown in FIG. **3a**;

FIG. **6** illustrates a section view of the detail of FIG. **1** through the line VI-VI shown in FIG. **5**.

**DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENTS OF THE INVENTION**

The electric machine described in detail below is specifically an electric motor. However, the technical characteristics and the teachings of the present invention also apply to other rotary electric machines, in particular to electricity generators.

With reference to the accompanying drawings, the numeral **1** denotes in its entirety an electric motor according to the present invention.

The electric motor **1** comprises a casing **2** to define an outer shell, a stator **3** permanently associated inside the casing **2**, and a rotor which is not illustrated since it is not relevant to the present invention.

Preferably, the electric motor **1** in accordance with the present invention is of the sealed type. For this purpose, the casing **2** comprises a substantially cylindrical lateral wall **2a** and a bottom wall **2b** rigidly connected to the lateral wall **2a** to define a single body with a bell shape. On the opposite side to the bottom wall **2b**, the lateral wall **2a** has a substantially circular opening "A" and it is permanently associated with a closing cap or cover, which is not illustrated, in particular by means of flanges **2c** jutting out from the lateral wall **2a**. The bottom wall **2b** is also fitted with a central hole "F" used to house a bearing

The stator **3** is of the wound type, and comprises a stator body **4** with a toroidal shape and defined by a plurality of

3

superposed laminations **4a** packed together to define a single body, as illustrated in FIG. 4. The stator body **4** has at least one polar expansion **5**, preferably a plurality spaced at equal angular intervals. Each polar expansion **5** extends radially towards an axis "X" of the stator **3** around which the stator **3** extends to coincide substantially with an axis of rotation of the rotor.

As shown in FIG. 4, the stator **3** also comprises a pair of half shells **6, 7** made from insulating material and which may be associated together to substantially envelop all the above-mentioned polar expansions **5**. In particular, the two insulating half shells **6, 7** define electrical insulating elements between the winding **8** and the polar expansion **5** and they approach each other from opposite sides of the stator body **4** along a direction parallel to the above-mentioned axis "X" of the stator **3**. More in detail, each half shell **6, 7** has an annular portion **6a, 7a** and a plurality of protruding portions **6b, 7b** each to be used to at least partially envelop a respective polar expansion **5**.

Each polar expansion **5**, covered with the respective pair of protruding portions **6b, 7b**, defines a core on which a respective stator winding **8** may be formed. As shown in FIG. 2, each winding **8** has an annular form and comprises a plurality of adjacent and/or superposed turns connected in series, obtained by winding a single lead wire around the above-mentioned core. The presence of the protruding portions **6b, 7b** of the insulating half shells forms an electrical insulation of the winding **8** with respect to the corresponding polar expansion **5**. FIG. 2 illustrates the stator **3** after the windings **8** have been formed.

The stator **3** is inserted in the casing **2**, in particular by means of a customary keying or shrinking-on process, in which a cylindrical lateral surface **9** of the stator body **4** is coupled with a corresponding cylindrical inner surface **10** of the casing **2**, in order to reach a configuration illustrated in FIGS. 1 and 5. The stator **3** is inserted in the casing **2** along the above-mentioned axis "X" of the stator **3**.

FIG. 3 illustrates in detail the angular distribution of the twelve polar expansions **5** placed at angular intervals from each other, preferably equally spaced.

Advantageously, the bottom wall **2b** of the casing **2** has at least one butting portion **11** to engage, preferably by supporting, with a portion **12** of the winding **8** to enable heat exchange from the portion **12** of the winding **8** to the butting portion **11** in order to cool the winding **8**. In order to improve this cooling effect, and in accordance with an embodiment not illustrated, the bottom wall **2b** of the casing **2** has an outer surface, that is to say, facing the outside of the electric motor **1**, fitted with fins to favour heat exchange between the bottom wall **2b** and the outside environment.

Preferably, the butting portion **11** is substantially shaped to match an outer shape of the portion **12** of the winding **8** which it holds, and it is defined by a protrusion **13** formed on the bottom wall **2b** of the casing **2**. The protrusion **13** extends away from the bottom wall **2b** to a space inside the electric motor **1**, and it faces a direction preferably parallel to the axis "X" of the stator **3**. The portion **12** of the winding **8** which engages with the protrusion **13** is, in particular, a front portion of the winding **8** facing the bottom wall **2b** of the casing **2**, along a direction for inserting the stator **3** in the casing **2**.

The protrusion **13** has a rounded butting surface **14** whose concavity faces the opposite side with respect to the bottom wall **2b**, that is to say, faces the above-mentioned space inside the electric motor **1**. The butting surface **14** may therefore be engaged with the portion **12** of the winding **8**, the portion **12** of which is part of the toroidal form of the winding **8** and is therefore curved and, more in detail, convex.

4

As shown in FIG. 3b, the bottom wall **2b** has a plurality of protrusions **13**, in particular twelve protrusions **13** spaced at equal angular intervals and placed around the axis "X" of the stator **3**. The protrusions **13** are located on the bottom wall **2b** at the positions adopted by the respective portions **12** of the windings **8** after assembly of the electric motor **1**, that is to say, after the stator **3** has been fitted in the casing **2**.

Advantageously, between each protrusion **13** and the respective portion **12** of the winding **8** there is at least one intermediate element **15**, either rigid or flexible, made from a thermally conductive and electrically insulating material. Preferably, the intermediate element **15** is in the form of a shim **16** and is removably fitted between the protrusion **13** and the portion **12** of the winding **8** to enable transfer of thermal power between the protrusion **13** and the portion **12** of the winding **8** whilst maintaining them electrically insulated, in order to avoid short circuits.

Preferably, the intermediate element is a shim made of Silpad®, and has at least the property of mechanical compressive strength.

In its undeformed state, the shim **16** extends mainly in one plane over an area with a size, measured along this plane, at least equal to a potential surface of contact between the protrusion **13** and the portion **12** of the winding **8**, so as to insulate the entire butting surface **14** of the protrusion **13** with respect to the winding **8**.

Advantageously, the electric motor **1** comprises thrust means **17** active on the portion **12** of the winding **8** to maintain the above-mentioned portion **12** pressed against the respective protrusion **13**. The above-mentioned thrust means **17** are mounted on the stator **3** and comprise at least one elastic element **18** active between the above-mentioned portion **12** of the winding **8** and the stator body **4**, in particular the polar expansion **5** of the stator body.

According to a preferred embodiment illustrated in FIGS. 5 and 6, each elastic element **18** is placed between the stator body **4** and the lower half shell **7** and, in more detail, between a lower surface **21** of the stator body **4** and an upper surface **22** of the respective protruding portion **7b** of the lower half shell **7**.

Basically, the stator body **4** and the lower half shell **7** delimit a space "S", which is illustrated not in proportion for greater clarity, in which the elastic element **18** is housed.

The space "S" is delimited above by the lower surface **21** of the stator body **4**, and below by the upper surface **22** of the respective protruding portion **7b** of the lower half shell **7**.

The elastic elements **18** are positioned in the space "S" before the windings **8** are formed.

Each portion **12** of the winding **8** engaging with the respective butting portion **11** is movable away from the stator body **4** under the action of the elastic element **18**. In addition, the lower half shell **7** keyed to the polar expansion **5** slides on the polar expansion **5** itself.

A stator **3** of the type described above, that is to say, fitted with an elastic element **18** for each winding **8**, may be inserted inside the casing **2** along the axis "X" of the stator **3**, until it abuts the portions **12** of the windings **8** against the respective protrusions **13** through the above-mentioned interposed shims **16**. In particular, the stator **3** is pushed along its axis "X" until the portion **12** of each winding **8** enters into contact with the respective protrusion **13** formed on the bottom wall **2b** of the casing **2**, and it is further pushed until it compresses each elastic element **18**. Following this compression, the stator **3** is permanently fixed, for example on an abutment ledge, not illustrated, preferably in an irreversible manner.

5

Basically, the stator is inserted, for example hot, inside the casing until it reaches an operational position identified by the abutment ledge at which it is permanently fixed.

In this position the elastic elements **18** apply a predetermined perpetual and substantially constant thrust on the corresponding portion **12** of the winding **8**, that is to say, on the lower half shell **7**. This results in a significant advantage if shims **16** are used, the electrical insulation and thermal conductivity properties of which reach optimum values if subjected to a substantial surface pressure, for example at least 1.5 kg/cm² in the case of Silpad® shims.

As described above, the stator **3** is fixed to the casing **2** by interference between the lateral cylindrical surface **9** of the stator body **4** and the inner cylindrical surface **10** of the casing **2**. If this interference is obtained by shrinking on, in which an expansion of the casing **2** is generated, the thrust action on the stator **3** against the bottom wall **2b** of the casing **2** is maintained until the stator **3** has been fixed, that is to say, until a stabilisation of the above-mentioned interference has been reached. In this way, there is no risk of elastic return of the elastic elements **18** during a cooling of the casing **2**, which would cause a loss or reduction of the compressive action on the above-mentioned shims **16**.

The present invention achieves the above-mentioned aims and overcomes the shortcomings of prior art.

The electric machine according to the present invention provides an effective cooling action thanks to the adoption of Silpad® shims which enable heat exchange by conduction between the windings and the casing without this contact generating short circuits in the windings. Consequently, it is possible to contain the maximum operating temperatures of the windings, which can therefore be used longer without this causing deterioration of the conductivity properties of the windings, nor decay of the insulating properties of the half shells keyed to the stator body.

Lastly, the presence of the thrust means active on the windings enables the stator to be fitted on the casing maintaining a substantially constant thrust action, with a desired value, of the windings against the protrusions of the casing. This thrust may be in particular determined to achieve optimum operation of the Silpad® shims. Moreover, the mechanical compressive strength exhibited by the Silpad® shims enables the shims to be "clamped" between the windings and the protrusions and, at the same time, to make an important contribution to the thermal conductivity and electrical insulation.

What is claimed is:

1. An electric machine comprising:

an outer casing;

a stator having at least one polar expansion and at least one winding having an annular shape and fitted around the polar expansion;

a rotor;

wherein the casing has at least one butting portion to engage with and support a portion of the winding to enable heat exchange between the winding and the butting portion, the portion of the winding being electrically insulated from the butting portion when engaged with the butting portion;

a plurality of thrust mechanisms, each active on one of the windings to maintain the winding pressed against the butting portion it is paired with;

wherein each thrust mechanism comprises at least one elastic element active between the winding and the polar expansion it surrounds;

wherein the winding is wound on the respective polar expansion to form a space between the winding and the

6

polar expansion it surrounds, the elastic element being positioned inside the space.

2. The electric machine according to claim **1**, wherein the space is delimited on one side by an electrically insulating element active between the polar expansion and the winding, and on another side by the winding.

3. The electric machine according to claim **1**, wherein the elastic element provides a biasing force between the winding and the polar expansion to bias the winding away from the polar expansion toward the butting portion.

4. The electric machine according to claim **3**, wherein the space is delimited on one side by an electrically insulating element active between the polar expansion and the winding, and on another side by the winding.

5. A method for the manufacture of an electric machine, comprising the steps of:

providing a casing having a lateral wall and a bottom wall;

providing a stator having at least one polar expansion and extending around an axis to coincide with an axis of rotation of a corresponding rotor of the electric machine;

forming a winding of a lead wire around the polar expansion;

inserting the stator in the casing along a line parallel to the axis of the stator;

wherein the step of forming the winding comprises the steps of:

winding the lead wire around the polar expansion to form a space between a portion of the winding and the polar expansion, the space facing from the polar expansion toward the bottom wall of the casing;

placing an elastic element in the space to provide a biasing force between the winding and the polar expansion to bias the winding away from the polar expansion toward the bottom wall of the casing;

placing, between the winding and the bottom wall, a thermally conductive and electrically insulating intermediate element;

the step of inserting the stator in the casing comprises the step of pressing the stator along its axis to abut the winding against the bottom wall to compress the elastic element.

6. The method according to claim **5**, wherein the step of forming the space comprises forming the space between the polar expansion and an electrically insulating element active between the polar expansion and the winding.

7. The method according to claim **5**, wherein the step of winding the lead wire on the polar expansion comprises winding the conductor loosely on the polar expansion to define the space, and subsequently inserting the elastic element in the space.

8. The method according to claim **5**, wherein the step of winding the lead wire on the polar expansion comprises associating the elastic element with the polar expansion and subsequently winding the lead wire on the polar expansion associated with the elastic element in order to form the space within which the elastic element is housed.

9. The method according to claim **5**, wherein the bottom wall of the casing has at least one protrusion, the step of inserting the stator in the casing being performed to abut the portion of the winding against the protrusion.

10. The method according to claim **5**, wherein the step of inserting the stator in the casing comprises a step of permanently fixing the stator to the casing, the step of pressing the stator along its axis being maintained until the stator has been fixed.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 8,362,662 B2
APPLICATION NO. : 12/671779
DATED : January 29, 2013
INVENTOR(S) : Pietro De Filippis

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 177 days.

Signed and Sealed this
First Day of September, 2015



Michelle K. Lee
Director of the United States Patent and Trademark Office